NEW SOLID STATE ACTUATORS FOR BIOMORPHIC EXPLORERS

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As solid state actuators for space applications, piezoelectric, magnetostrictive and shape memory materials are popularly studied. This paper deals with two new solid state actuators from a viewpoint of space applications: artificial muscles and photostrictors.

The artificial muscle is an electrostatic actuator consisting of thin polymer films. Interdigital electrodes are embedded in polymer films and are excited by a 3-phase voltage, choosing a suitable phase lag between polymer films. Using a dual excitation multiphase electrostatic drive, 40 layer 12 um thick PET films with 80 mm in length and 34 mm in width (total weight = 43g), immersed in 'Fluorinat', could provide a speed of 1 m/sec and a force of 320N at 10 Hz of 2.5 kV. Though this actuator can provide a superior power/weight ratio, very large applied voltage and usage of liquid must be carefully considered.

Photostriction in ferroelectrics arises from a superposition of photovoltaic and inverse piezoelectric effects. (Pb,La)(Zr,Ti)O3 ceramics doped with WO3 exhibit large photostriction under irradiation of near-ultraviolet light, and are applicable to remote control actuators and photoacoustic devices. This paper reviews basic investigations on photostriction in terms of composition, dopants, sample thickness and surface roughness. Then, the applications are introduced. Using a bimorph configuration, a photo-driven relay and a micro walking device have been developed, which are designed to start moving as a result from the irradiation, having neither electric lead wires nor electric circuits. The mechanical resonance of the bimorph was also induced by an intermittent illumination of purple-color light; this verified the feasibility of the photostriction to "photophone" applications. The basic idea for automatic solar chasing system will be presented.

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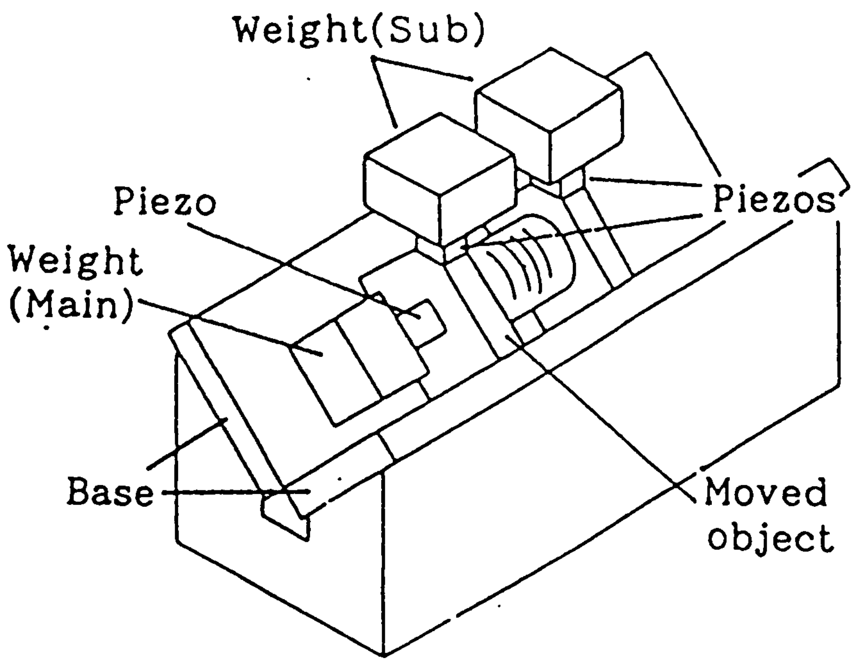
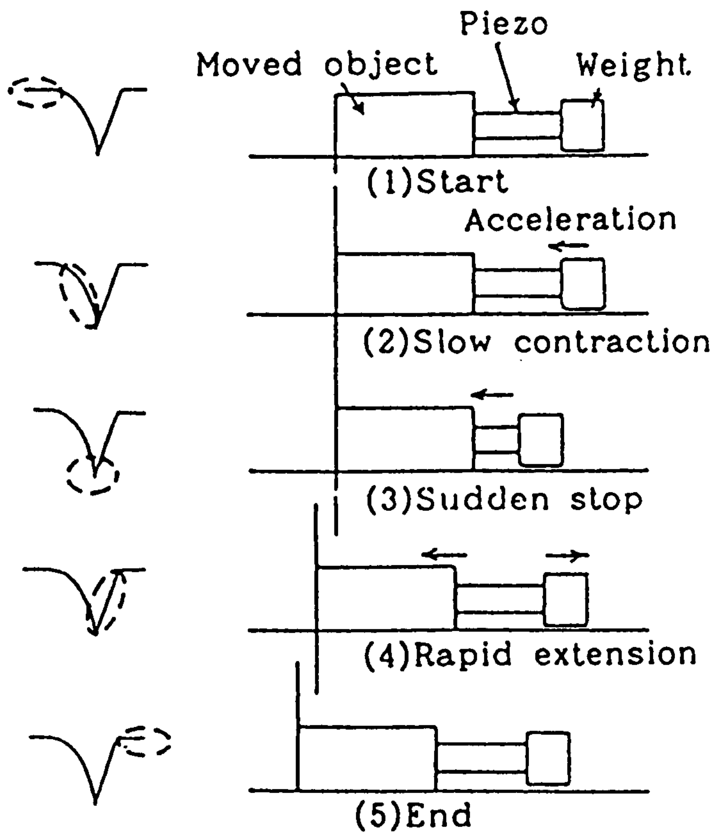
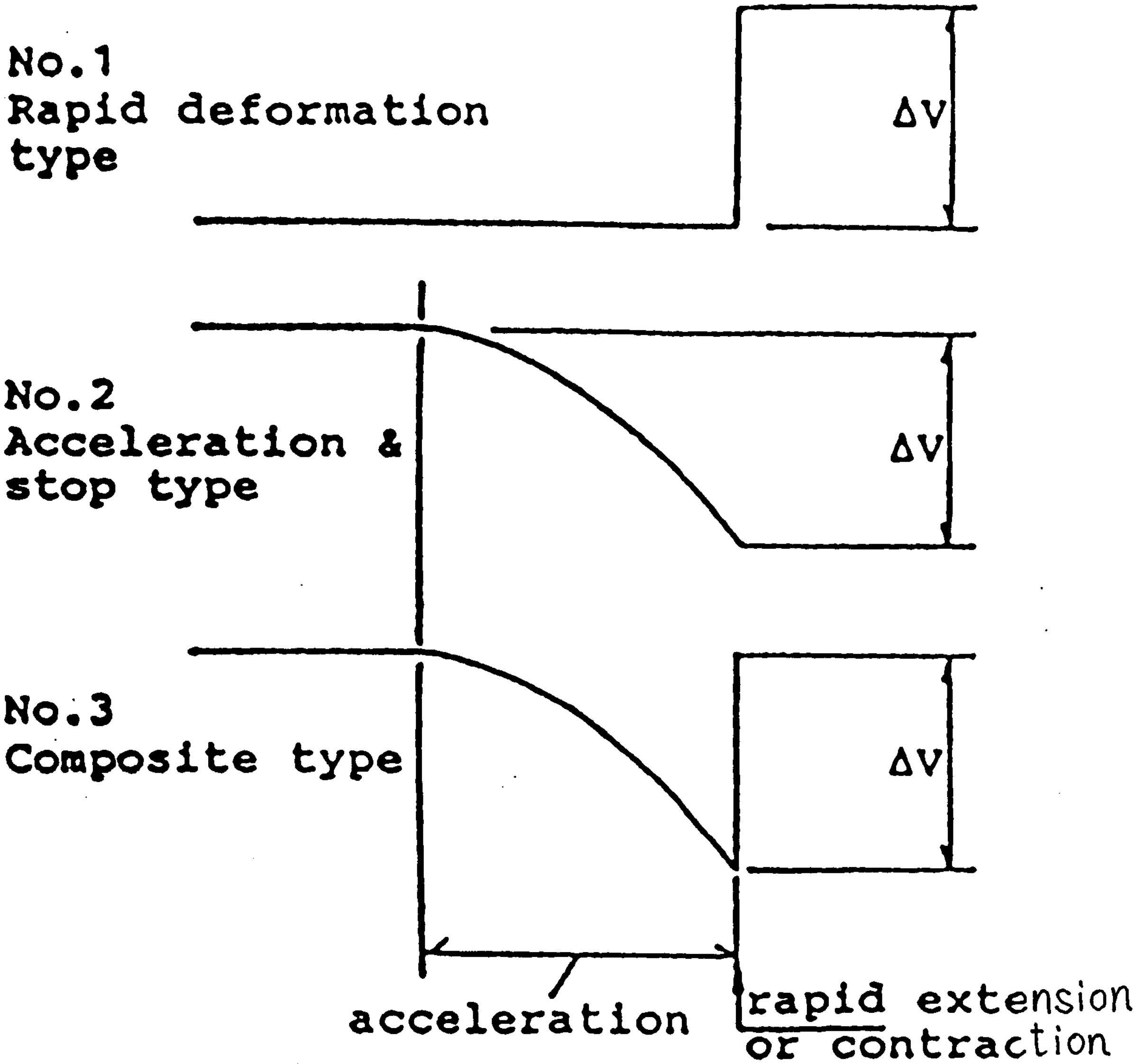
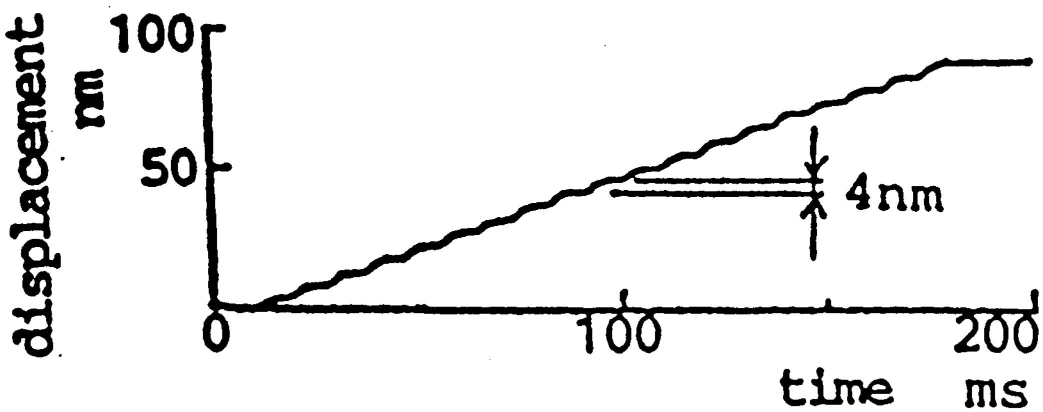


Impact Drive Mechanism

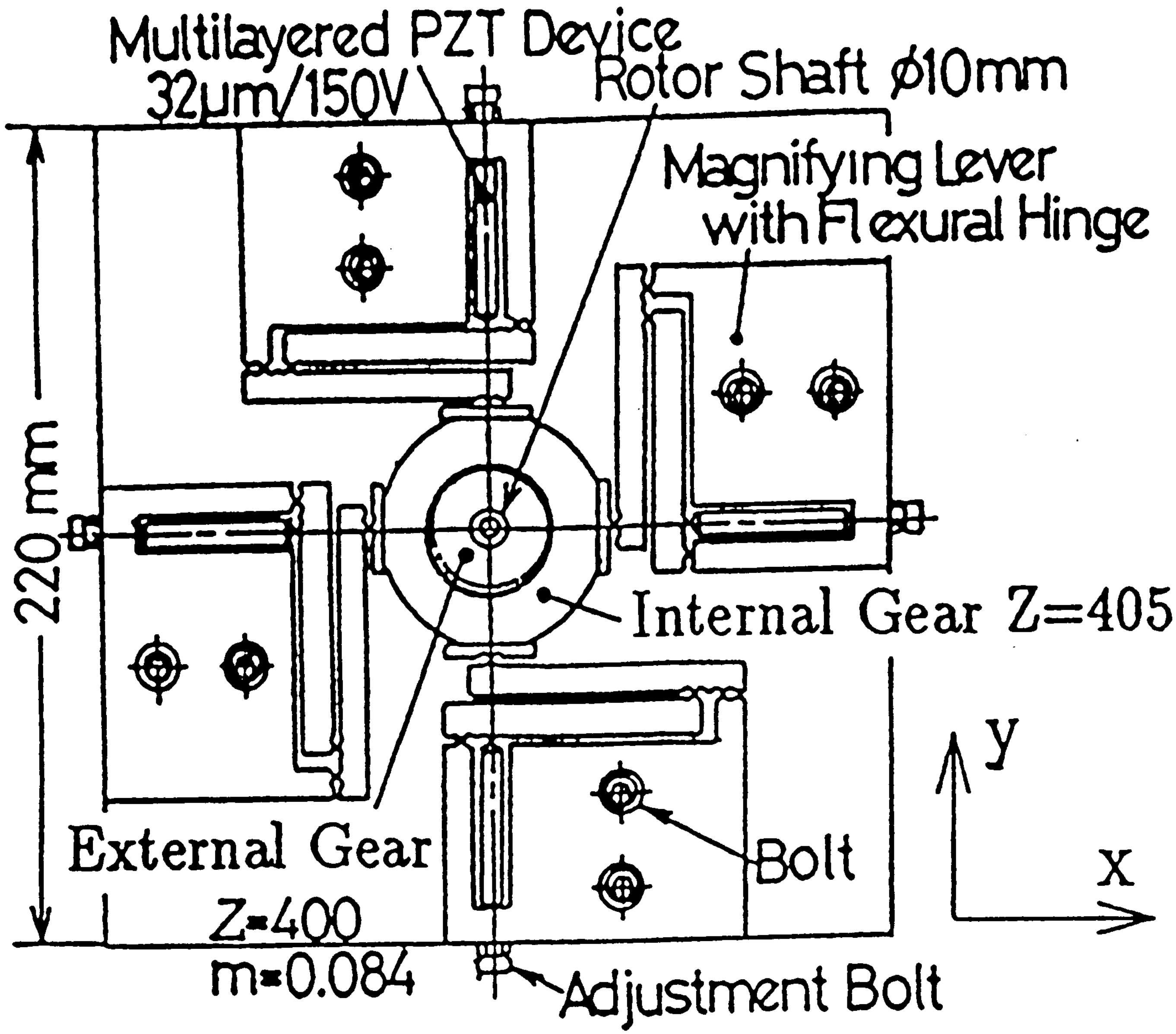


Principle of Impact Drive

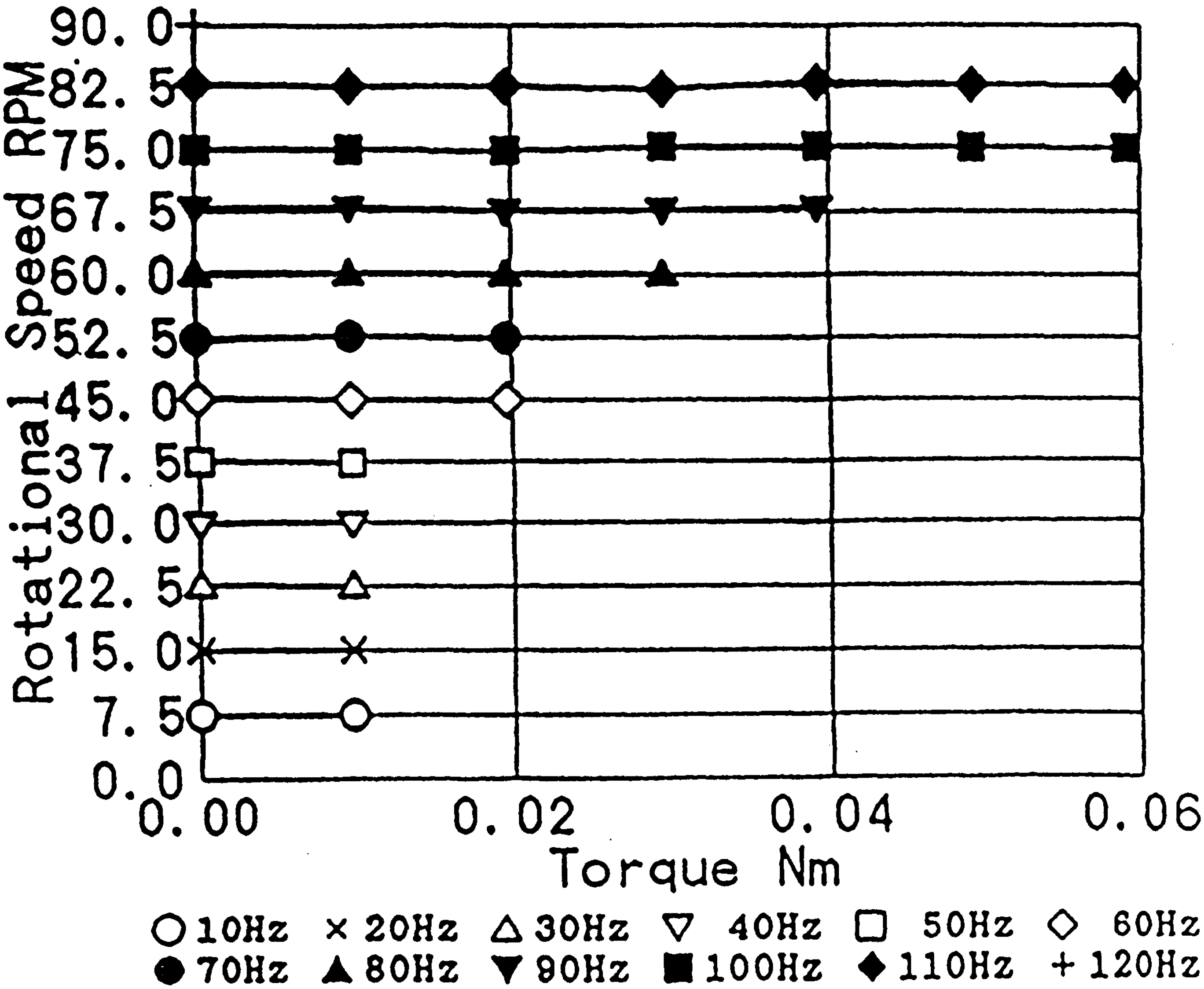




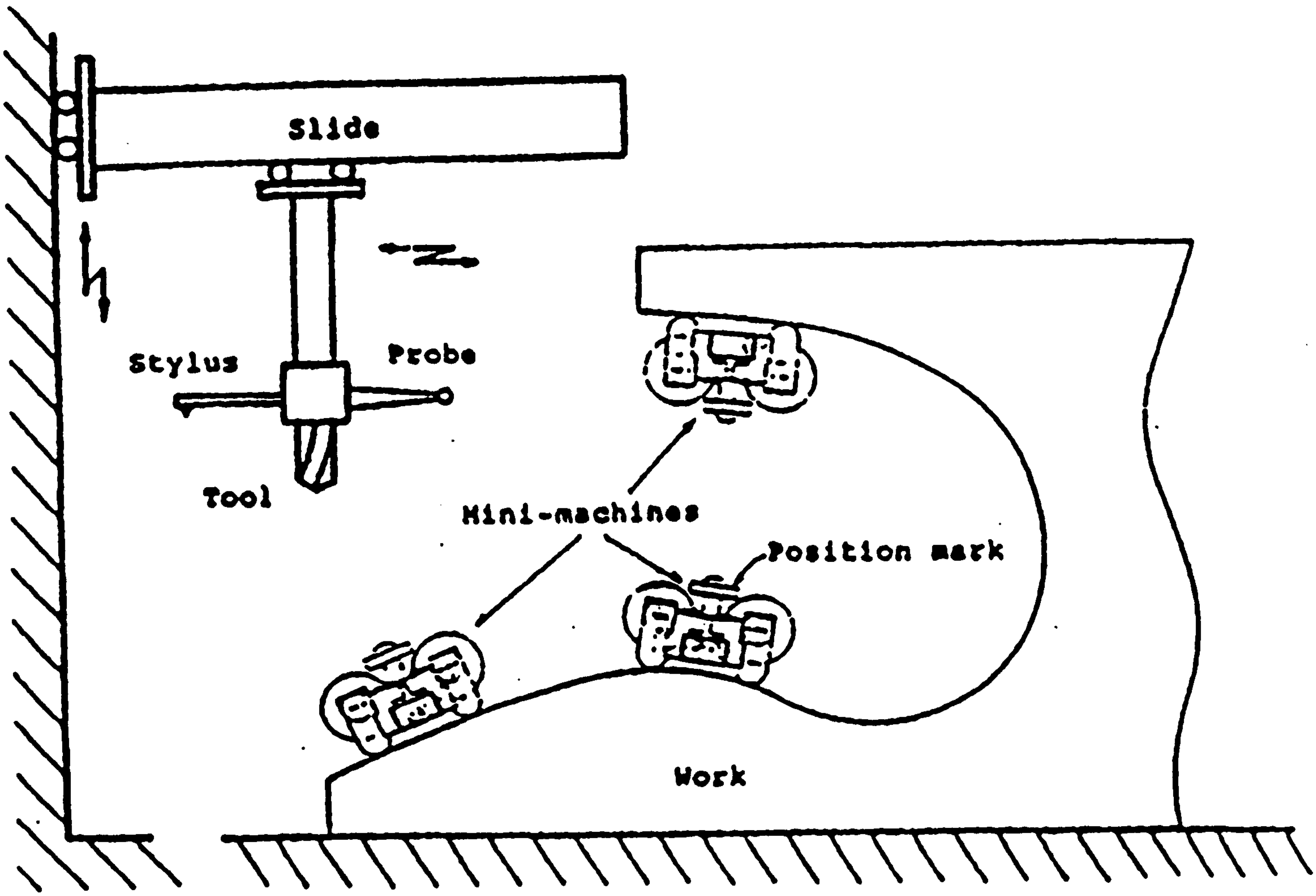
Nano-displacement Control by Impact Drive



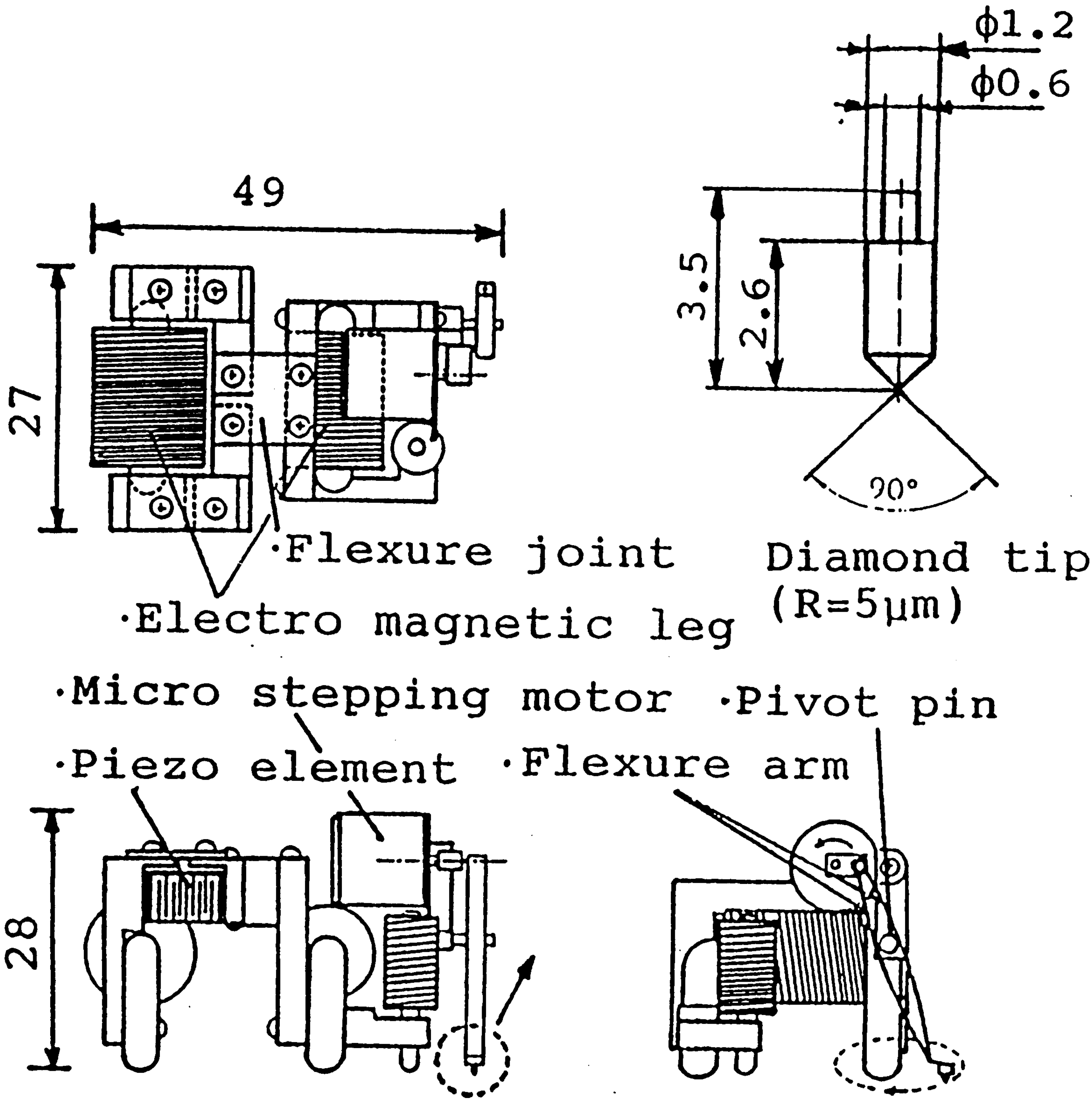
Piezoelectric Cycloid Motor



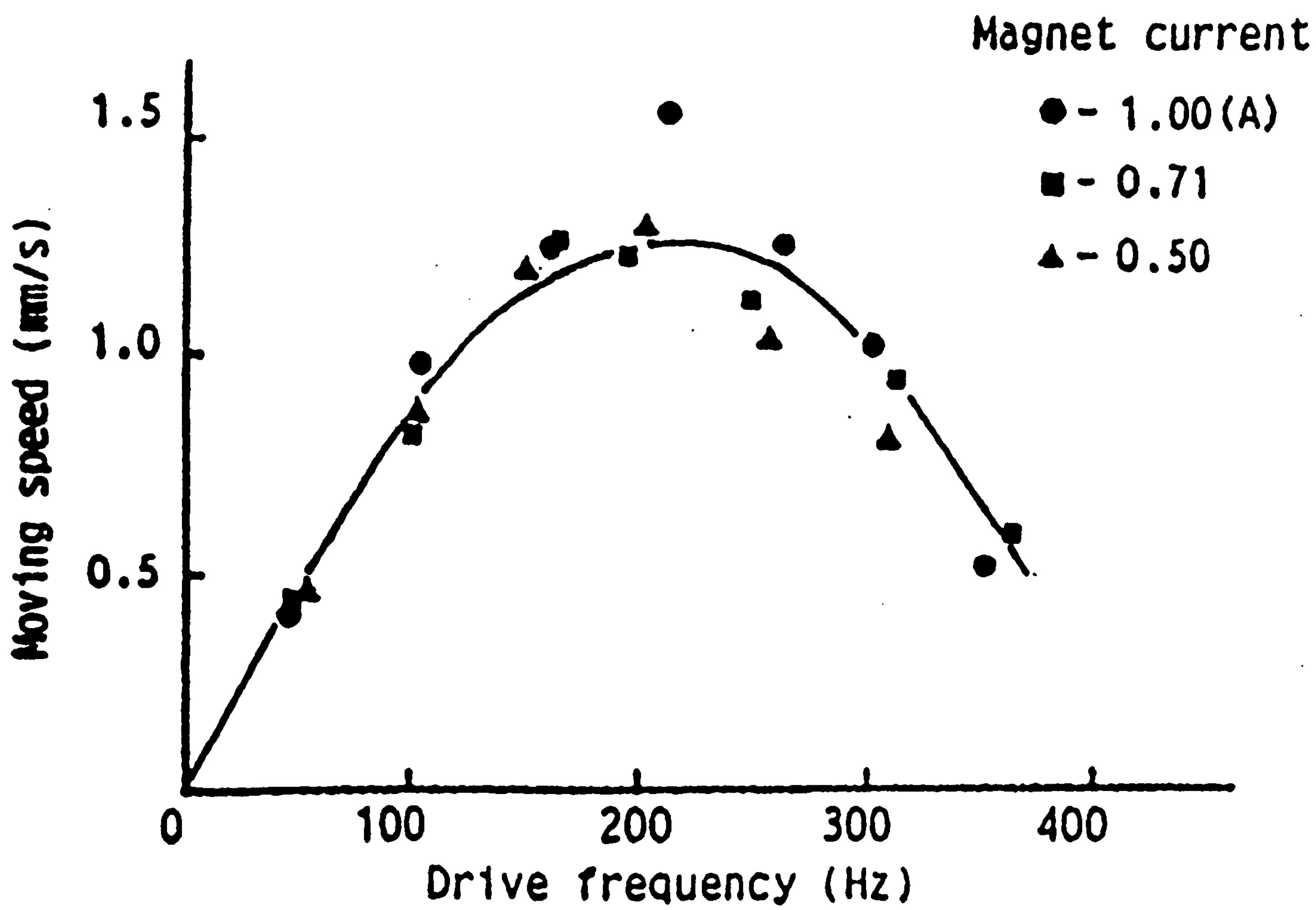
Revolution Characteristics under Load



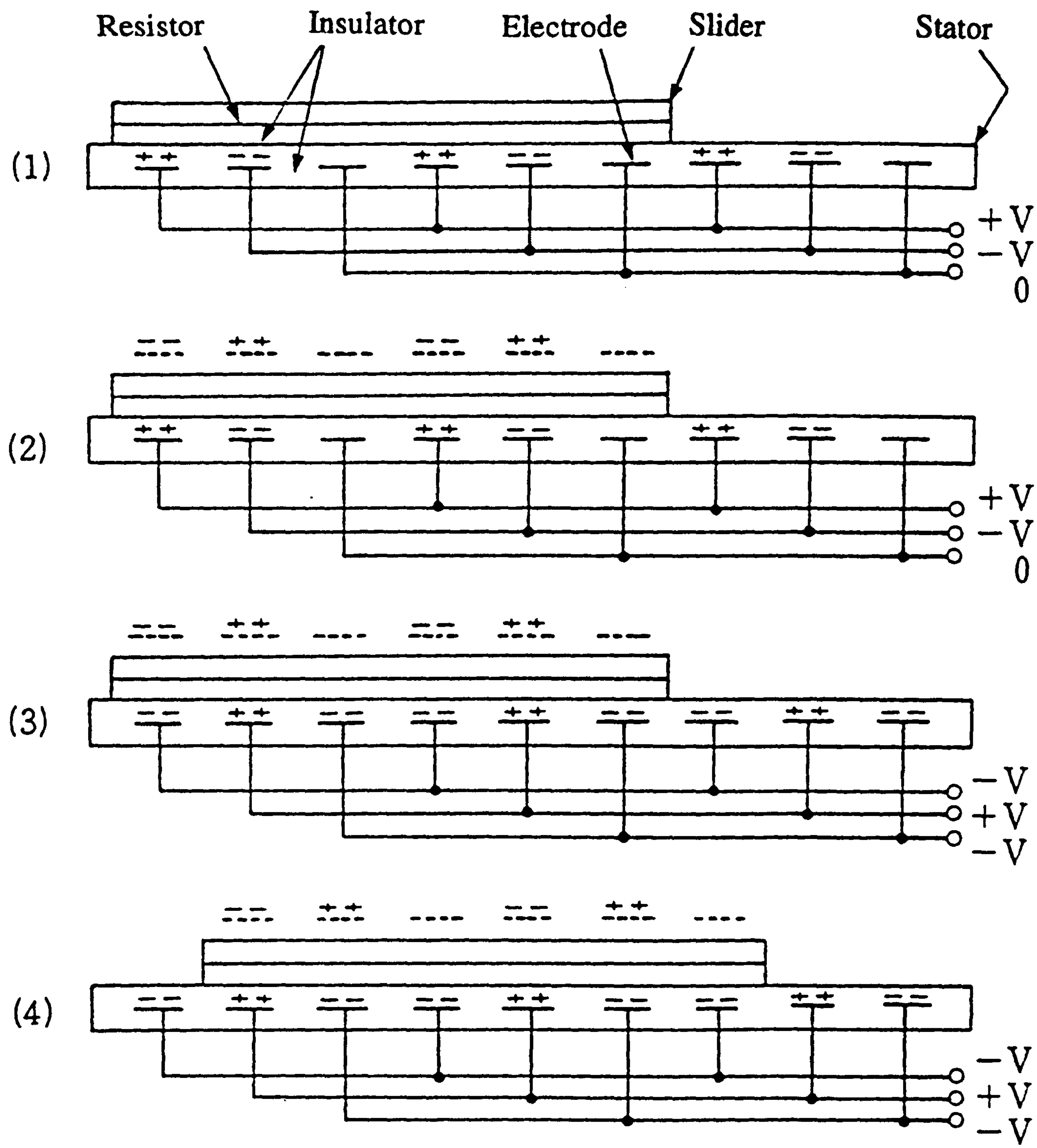
Machining Using Multiple Micro Moving Devices



Structure of Micro Moving Machine



Moving Speed of a Micro Moving Device



Principle of Electrostatic Motor

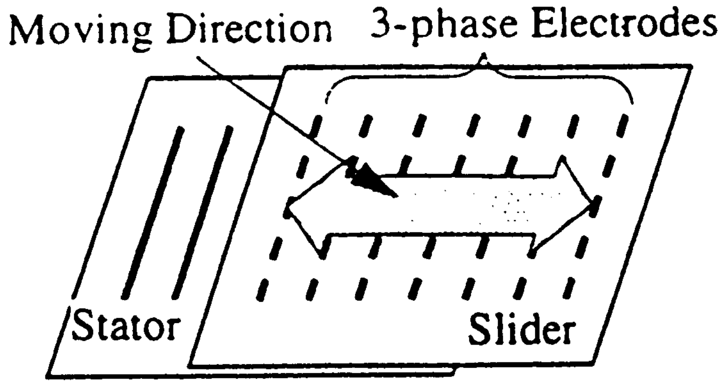


Fig. 1: Basic structure of a DEMED

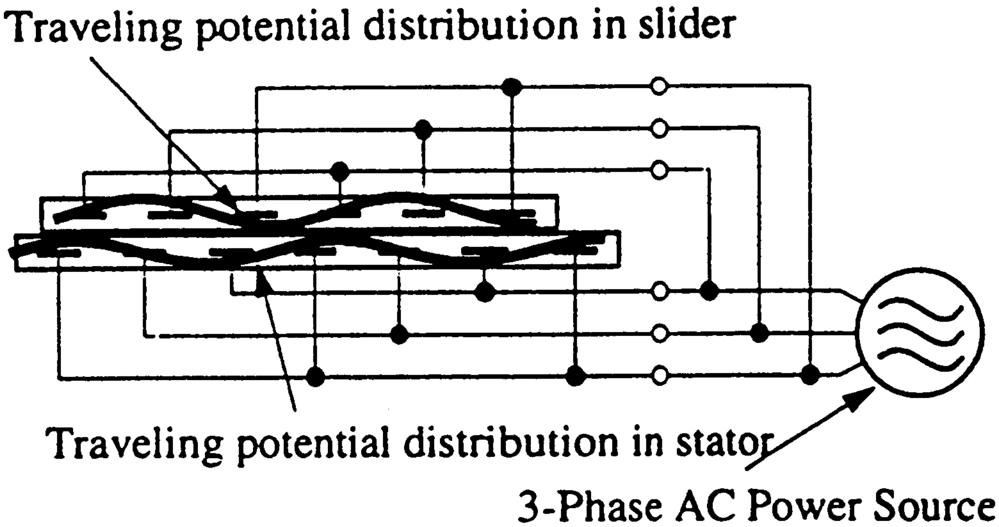


Fig. 2: Schematic cross sectional view of a DEMED

The speed of the slider usl can be written as

$$u_{sl} = \frac{6p\omega}{2\pi} \qquad (1)$$

where p and w are interval of electrodes and angular frequency of the AC respectively. This means a slider of a DEMED traverses 6 lines of stator's electrodes during one cycle of the applied AC.

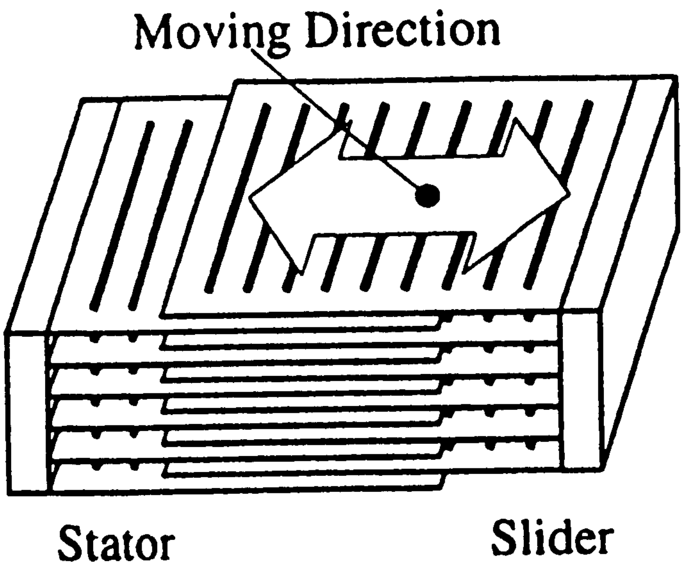


Fig. 4: Schematic view of multi-layer motor

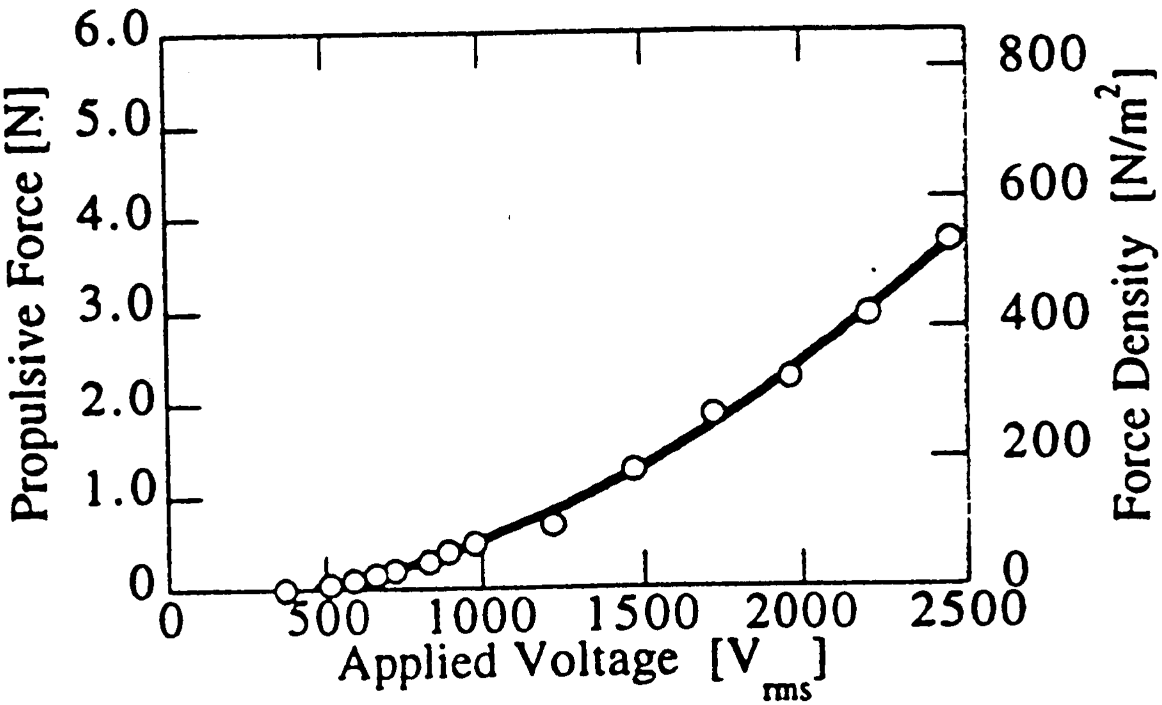
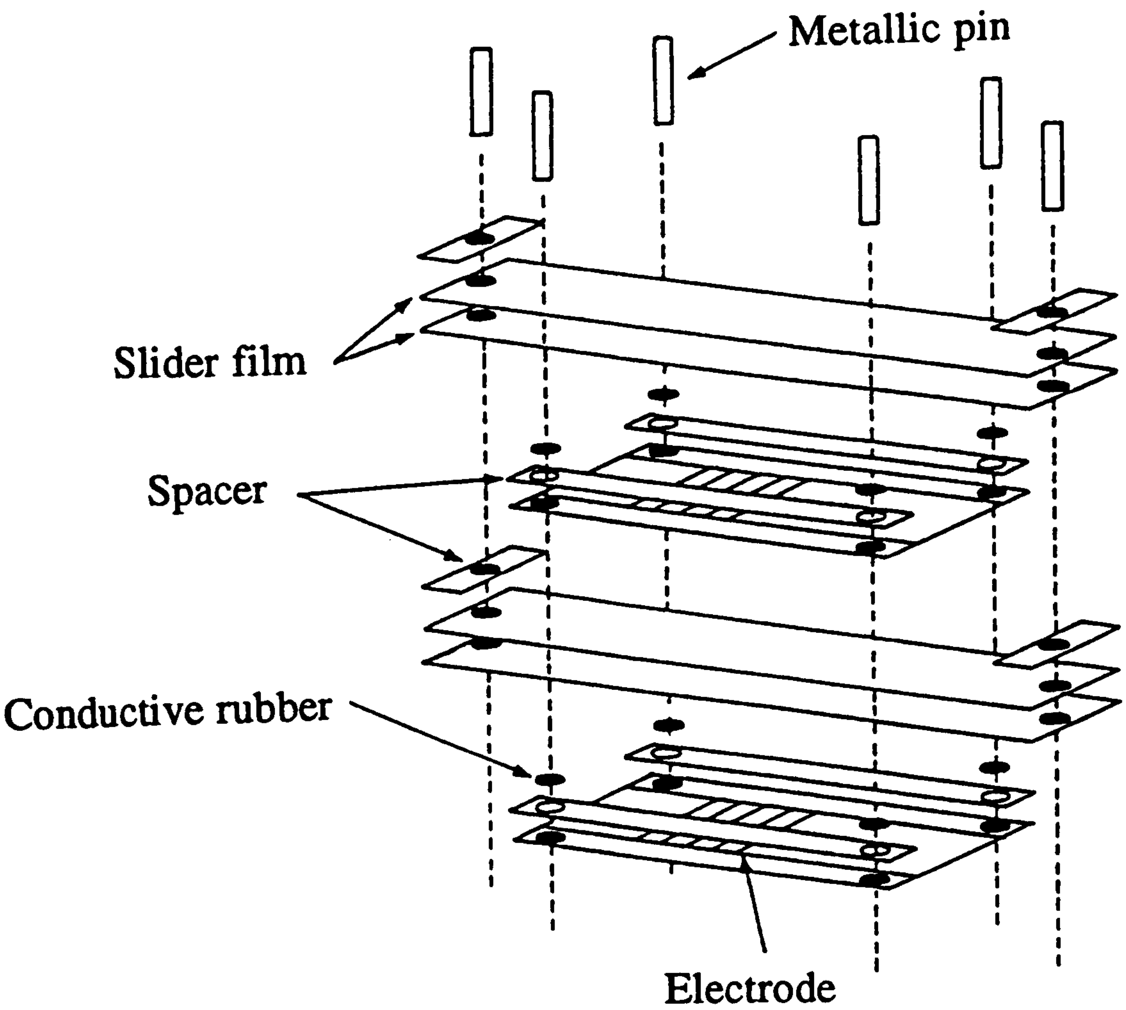
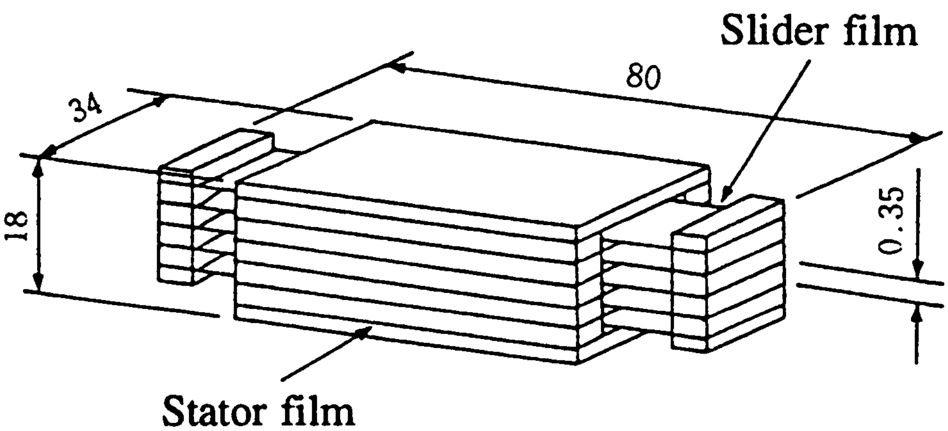


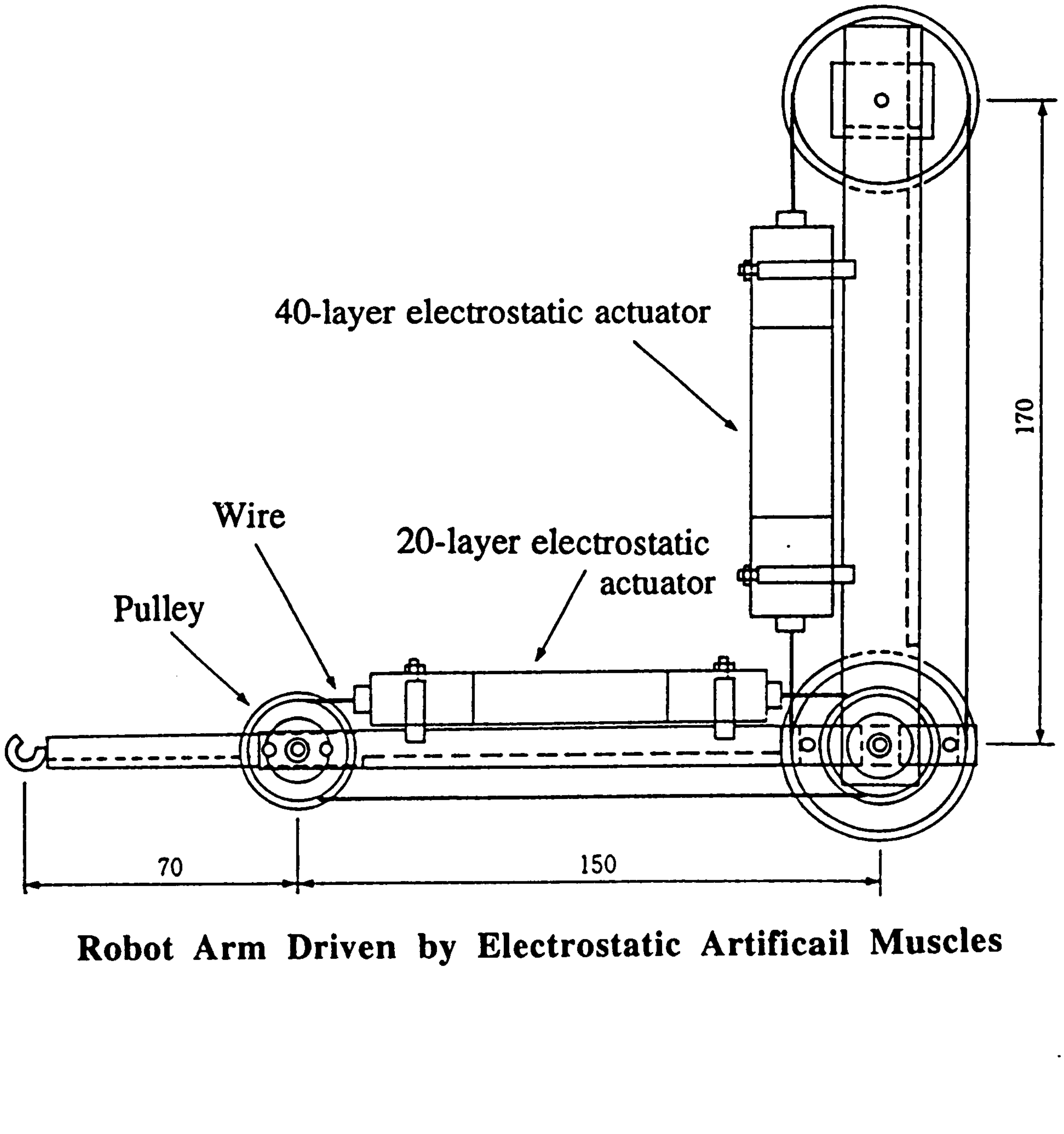
Fig. 3: Relationship between thrust force and excitation voltage of a linear type DEMED



Multilayer Structure



Prototype Actuator



Robot Arm Driven by Electrostatic Artificail Muscles

PHOTOSTRICTIVE EFFECT

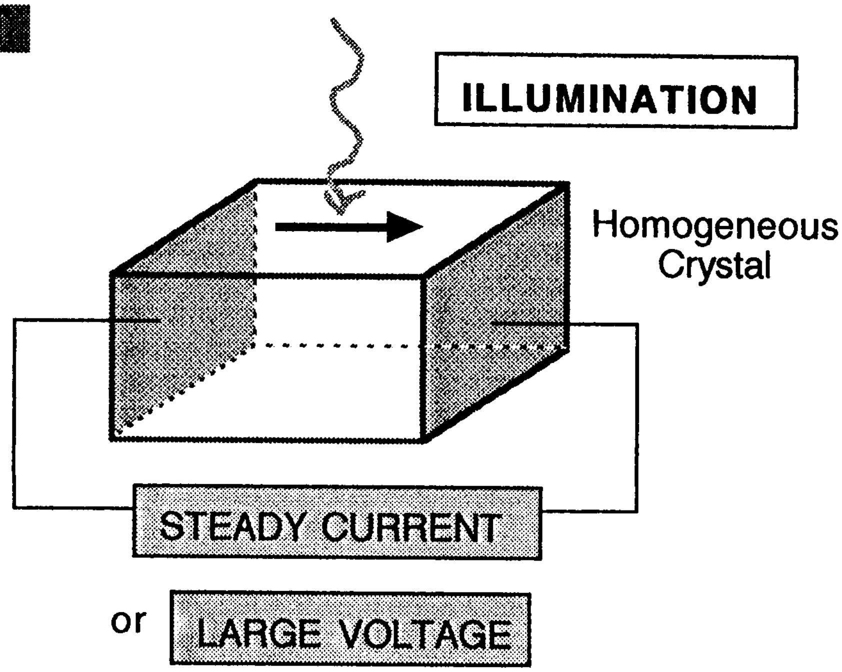
PHOTOVOLTAIC EFFECT

$J_{ph} = \kappa\, \alpha\, I$

$\sigma = \sigma_d + \sigma_{ph}$

$E_{ph} = \kappa\, \alpha\, I / (\sigma_d + \beta\, I)$

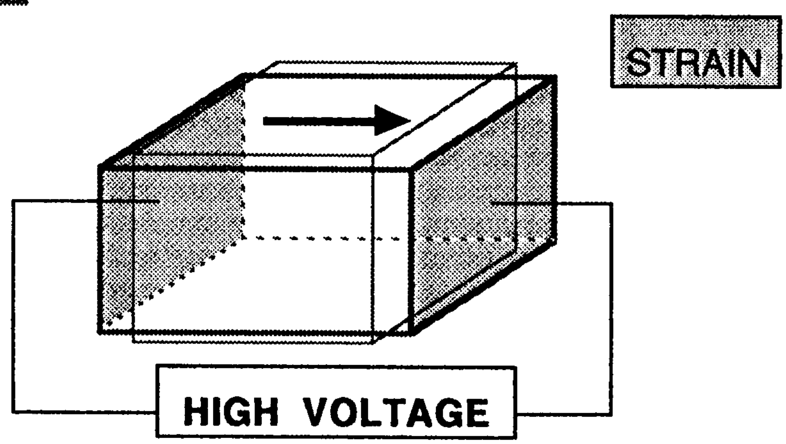
e.g. in PLZT
at 366 nm
E = 1 kV/mm



PIEZOELECTRIC EFFECT

$x_3 = d_{33}\, E_3$

$x_1 = d_{31}\, E_3$



EXPECTED PHOTOSTRICTION

$x_3^{ph} = d_{33}\, E_3^{ph}$

$x_1^{ph} = d_{31}\, E_3^{ph}$

Photo-driven Devices
Photoacoustic Devices

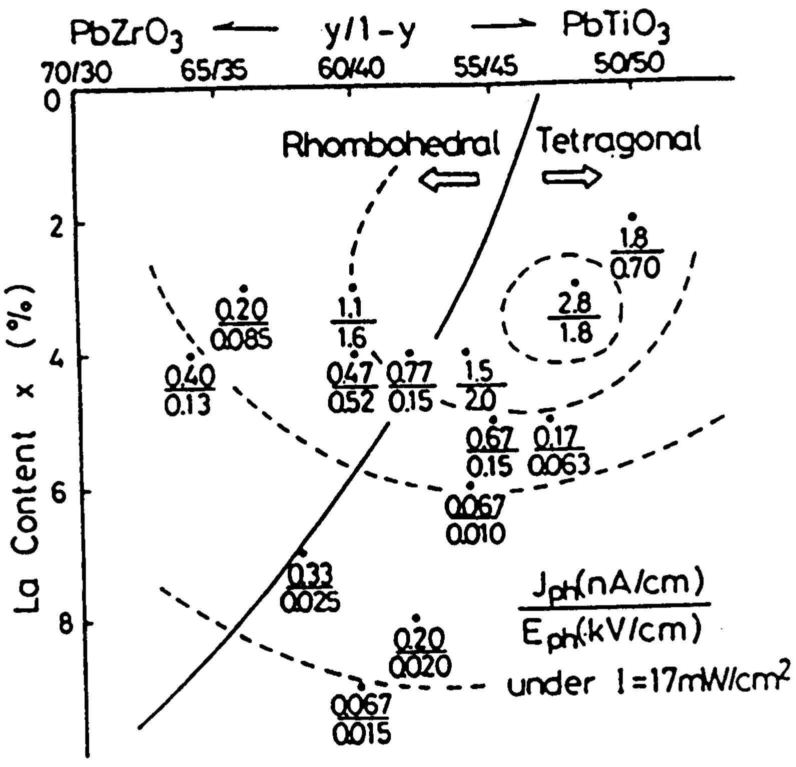


Fig.3. Photovoltaic current and voltage under illumination intensity of 17Wm/cm2 in $Pb_{1-x}La_x(Zr_yTi_{1-y})_{1-x/4}O_3$ phase diagram.

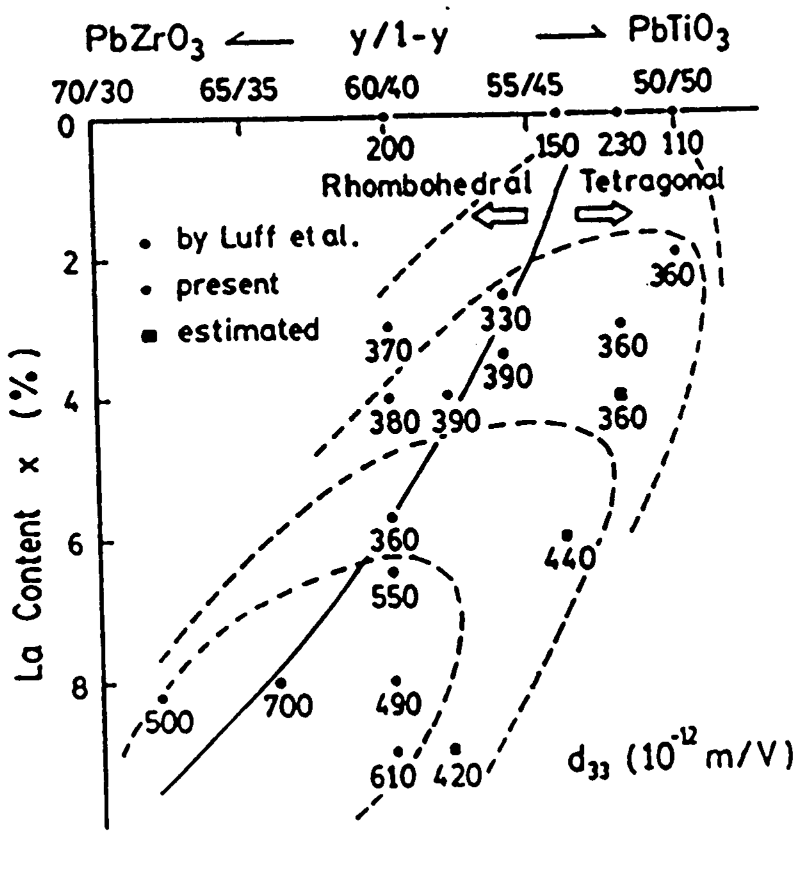
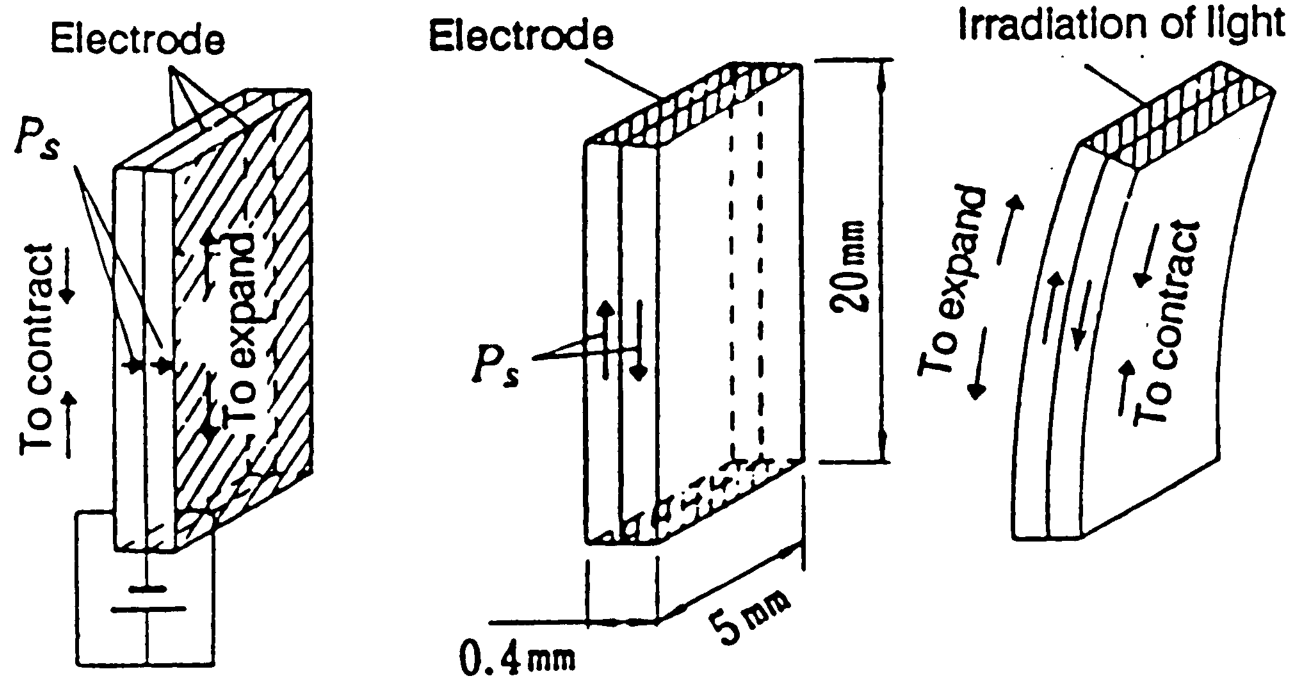


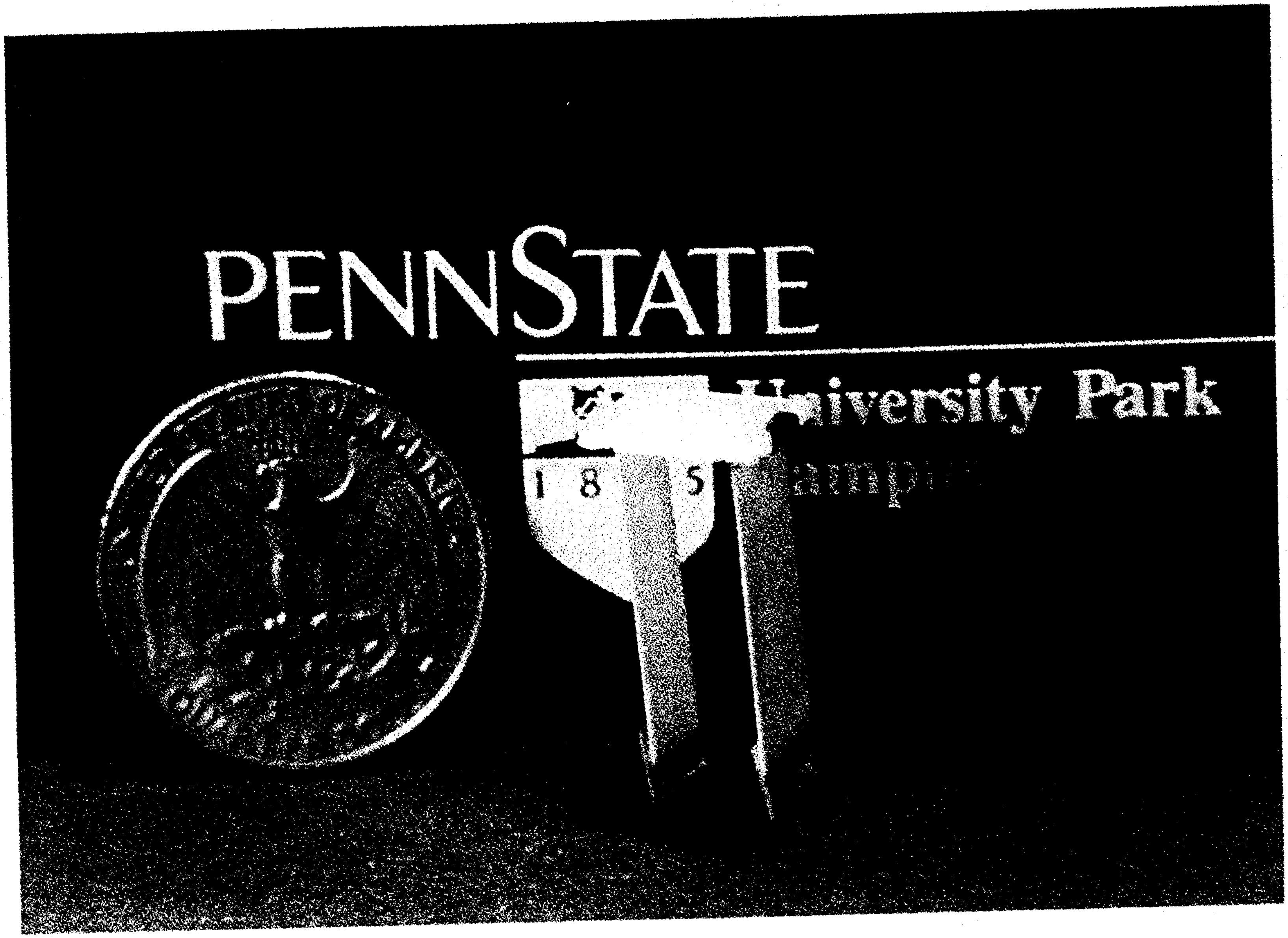
Fig.4. Piezoelectric coefficient d_{33} as a function of composition in $Pb_{1-x}La_x(Zr_yTi_{1-y})_{1-x/4}O_3$.



Structure of voltage-driving bimorph

Structure of photo-driving bimorph

Fig. 8. Structures of voltage-driving and photo-driving bimorphs and their driving principles


PENNSTATE
Park

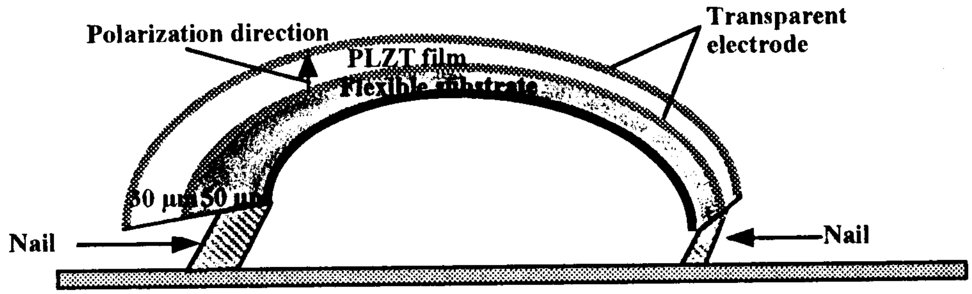
DEVICE DESIGN

PHOTOACTUATING COMPOSITE FILM

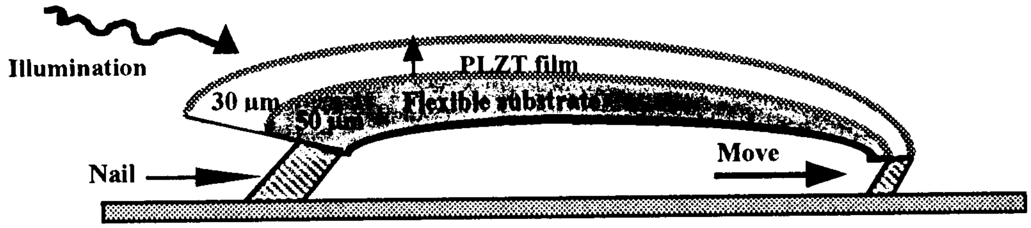
1. Prototype for flexible microactuator
2. Tailoring photostrictive film on flexible substrate
3. Slight difference between the right and left legs for rotation

1. Arc-shaped type unimorph

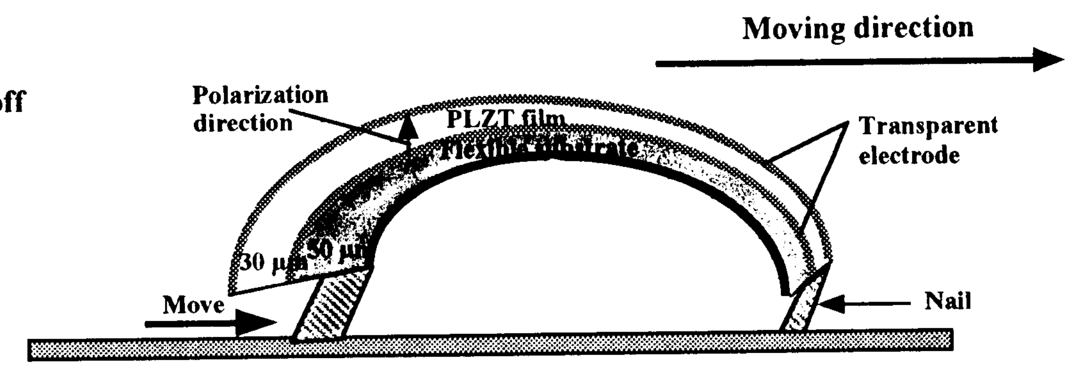
1. Initial Stage



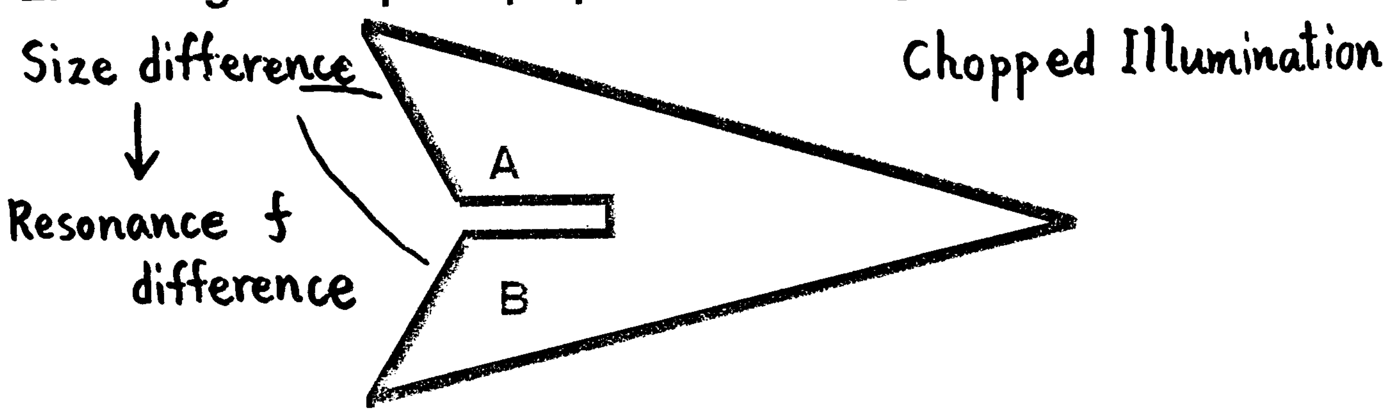
2. Illumination on



3. Illumination off



2. Triangular top shape photoactuating composite film

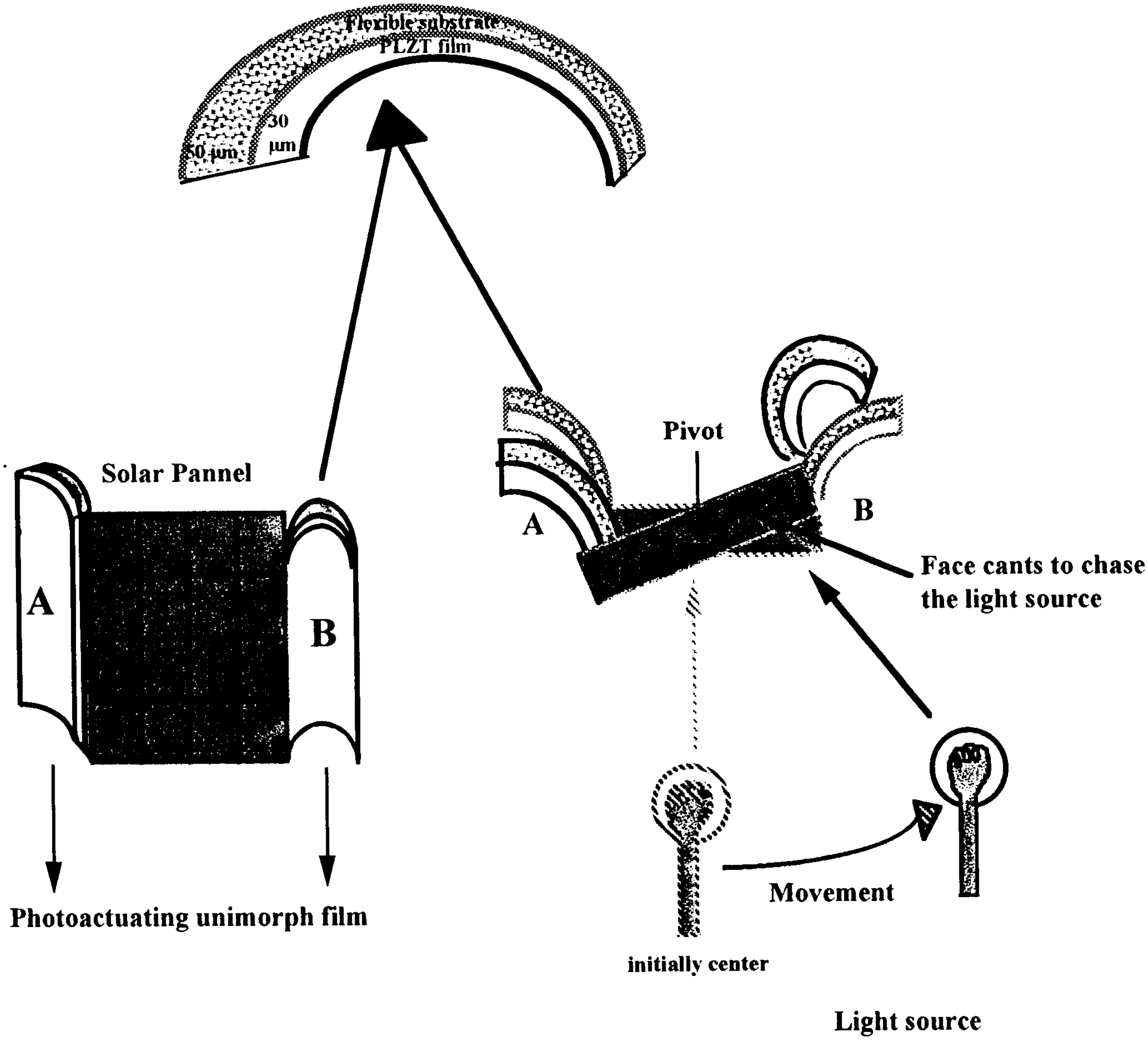


DEVICE DESIGN

Light source chasing device

1. Based on photoactuating film composites.

2. Utilized for chasing solar irradance by tailoring the absorption edge of PLZT.



SUMMARY

NEW SOLID STATE ACTUATORS FOR BIOMORPHIC EXPLORERS

1. **Piezoelectric Actuators**

   1.1 Impact Drive Actuator (Higuchi)
   precise positioning, impact force

   1.2 Cycloid Motor (Hayashi)
   high torque

   1.3 Micro Cutting Machine (Aoyama)
   combination of micro machines

2. **Electrostatic Actuators**

   Artificial Muscle (Higuchi)
   light weight actuator

3. **Photostrictive Actuators**

   Photo-driven Actuator (Uchino)
   remote control